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INFLUENCE OF THE LUNAR CYCLE ON THE ACTIVITY OF PHLEBOTOMINE SAND FLIES (DIPTERA: PSYCHODIDAE)

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ABSTRACT. The influence of lunar phases on the activity of phlebotomine sand flies was evaluated in Viçosa, Minas Gerais, Brazil. The insects were collected by illuminated Shannon traps and Falcão light traps, between 1830 and 2230 h on 44 nights, divided between the dry and rainy seasons, and among each of the 4 lunar phases. A total of 888 sand flies was collected, belonging to 10 *Lutzomyia* species. The dominant species in both seasons of the year and in all lunar phases was *Lutzomyia intermedia*. A significant difference was found in the abundance of *L. whitmani* among lunar phases. No significant difference was found in frequency of sand flies collected among lunar phases. Females of *L. intermedia* initiated activity earlier during the crescent and full moon phases than during three-quarter and new phases. Based on the premise that sand flies would exhibit normal phototaxis in the absence of moonlight, activity should be unaffected under a new moon, whereas light reflected by the moon in its brightest phases (crescent and full) should shift the period of activity of the sand flies so that it does not coincide with the period in which the moon is visible, or should reduce attractiveness of light traps to the insects by providing less background contrast.

KEY WORDS Lunar cycle, vector ecology, sand flies

INTRODUCTION

Adult phlebotomine sand flies typically exhibit nocturnal and crepuscular activity (Young and Duncan 1994). Although their movements around a host consist of short jumps, they are able to travel distances of at least 200 m in a single night (Chaniotis and Correa 1974, Alexander 1987). Some New World species of the genus *Lutzomyia* transmit *Leishmania* spp. as well as the bacterium *Bartonella bacilliformis* and certain arboviruses (Young and Duncan 1994).

The lunar cycle influences the adult flight behavior of many insects, particularly those with at least 1 aquatic phase of development, principally affecting reproductive behavior such as the initiation or regulation of mating swarms (Neumann 1995). The effects of lunar phases on the behavior of certain Diptera, particularly Culicidae, have been demonstrated. Janousek and Olson (1994) found that the attractiveness of light traps increased during a lunar eclipse and diminished under a full moon.

Few studies have demonstrated an influence of the phases of the moon on phlebotomine sand fly behavior (Aguiar et al. 1985). Based on existing knowledge of the biology of sand flies, one might expect these insects to be affected by the lunar cycle. Crepuscular species should show lower densities in light traps and longer periods of activity during moonlight nights, whereas the opposite should be true of nocturnal species.

In the present study, we investigated whether the activity patterns of some sand flies collected in light traps correlated with the different phases of the moon.

MATERIALS AND METHODS

The area chosen to carry out these observations was the microregion of Viçosa (20–21°S, 42–43°W), in the region known as the Zona da Mata Mineira, Minas Gerais State, Brazil, where the predominant climate is Cwa (Köppen), that is, moderately humid subtropical with a hydrological deficit from May to September and excess from December to March (Golfari 1975). The following three areas were selected within this microregion. Viçosa (20°45′20″S, 42°52′40″W) was located at 650–870 m above sea level (masl); had topographical relief characterized as 3% level, 12% undulating, and 85% mountainous; and had mean annual rainfall of 1,500–2,000 mm, relative humidity of approximately 80%, and annual temperature range of 14.0–26.1°C (IBGE 1999). Cajuri (20° 47′26″S, 42° 47′48″W) was located at 600–1,006 masl; had topographical relief characterized as 5% level, 30% undulating, and 65% mountainous; and had mean annual rainfall of 1,700 mm and annual temperature range of 14.4–26.5°C (IBGE 1999). Teixeiras (20°39′04″S, 42°51′24″W) was located at 607–929 masl; had topographical relief characterized as 18% level, 55% undulating, and 27% mountainous; and had mean annual rainfall of approximately 1,500 mm and annual temperature range of 14.0–26.0°C (IBGE 1999).

Sand fly sampling was carried out on 44 nights (from 1830 to 2230 h each night), between October 1999 and August 2000, during the dry (June, August; 24 nights) and rainy seasons (October, December, January, March; 20 nights). Sampling was conducted with an illuminated Shannon trap and 5 Falcão light traps (Aguiar et al. 1985). The collection period (from 1830 to 2230 h) has been de-

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Table 1. Mean abundance and the percent occurrence of phlebotomine sand flies collected during rainy and dry seasons, in illuminated Shannon traps, and Falcão light traps, in the microregion of Viçosa, Minas Gerais State, Brazil, between October 1999 and August 2000.[1]

Species	Rainy season Mean (SD)	Rainy season %	Rainy season Total	Dry Season Mean (SD)	Dry Season %	Dry Season Total	t-test (P)	χ^2 (P)
L. intermedia	11.70 (33.70)	65.0	234	20.04 (29.80)	87.5	481	0.86 (0.39)	3.14 (0.07)
L. whitmani	1.45 (2.93)	35.0	29	3.21 (6.85)	37.5	77	1.07 (0.29)	0.02 (0.86)
L. fischeri	0.45 (1.10)	20.0	9	1.08 (3.12)	25.0	26	0.93 (0.36)	0.15 (0.69)
L. lenti	0.65 (1.60)	30.0	13	0.33 (0.96)	12.5	8	0.78 (0.44)	2.05 (0.15)
L. migonei	0.15 (0.37)	15.0	3	0.04 (0.20)	4.1	1	1.24 (0.22)	1.54 (0.21)
L. monticola	0.00 (0.00)	0.0	0	0.13 (0.45)	8.3	3	—	—
L. ayrozai	0.05 (0.22)	5.0	1	0.00 (0.00)	0.0	0	—	—
L. edwardsi	0.05 (0.22)	5.0	1	0.00 (0.00)	0.0	0	—	—
L. misionensis	0.00 (0.00)	0.0	0	0.04 (0.20)	4.1	1	—	—
L. sordellii	0.05 (0.22)	5.0	1	0.00 (0.00)	0.0	0	—	—
Total			291			597		
n			20			24		

[1] SD, standard deviation; *L.*, *Lutzomyia*; n, number of samples.

scribed by many authors as having the most activity for many sand fly species in the Neotropical region (Forattini 1973, Gomes et al. 1989, Galati et al. 1996). Collections in the Shannon trap were divided into 30-min intervals, providing a total of 8 time periods per night. The collections were distributed among the different lunar phases as evenly as possible.

The Shannon trap was mounted at a minimum distance of 35 m from houses and their outbuildings. Five Falcão traps were placed around houses, animal shelters, edges of cropland, and forest borders (where present), about 35 m apart and the same distance from the houses and Shannon trap.

Sand flies captured were transported to the laboratory in 70% alcohol, cleared, and mounted in Berlese fluid for identification with the keys of Young and Duncan (1994), with confirmation based on comparison with the original descriptions and reference examples in the Quantitative Ecology Laboratory of the Federal University of Viçosa and the Leishmaniasis Laboratory of René Rachou Research Center/FIOCRUZ.

The nonparametric Kruskal–Wallis test was used to compare the means of the most abundant species captured during the different lunar phases. The t-test was used to compare the means of the most abundant species collected between the seasons (rainy and dry). The chi-squared test was used to compare the frequencies (the presence or absence in the samples) of the species during the different seasons. The Mann–Whitney U-test (Zar 1999) was used for a pairwise comparison of abundance with lunar phases, when Kruskal–Wallis analysis of variance was significant. The Kolmogorov–Smirnov test (Snedecor and Cochran 1980) was used to test the hypothesis that the distribution of the abundance of the sand flies among time intervals during the night sampling differs among the lunar phases.

RESULTS

A total of 888 sand flies was collected, belonging to 10 *Lutzomyia* species: *L. intermedia* (Lutz and Neiva), *L. whitmani* (Antunes and Coutinho), *L. fischeri* (Pinto), *L. lenti* (Mangabeira), *L. migonei* (França), *L. monticola* (Costa Lima), *L. ayrozai* (Barretto and Coutinho), *L. edwardsi* (Mangabeira), *L. misionensis* (Castro), and *L. sordellii* (Shannon and Del Ponte) (Table 1). Based on the geographic distribution and morphological characteristics presented by Marcondes et al. (1998a, 1998b), we considered the *L. intermedia* complex species encountered in our samples to be *L. intermedia* sensu stricto.

The most abundant species during the 2 seasons of the year and all lunar phases was *L. intermedia* (Tables 1 and 2). No significant difference was found in the frequency of the species during the rainy and dry seasons (Table 1). A significant difference was found in the abundance of *L. whitmani* among lunar phases (possibly due to the significant result found in male abundance; Table 2). Figure 1 shows that this species had a lower abundance at the crescent moon (Mann–Whitney U-test, $P < 0.03$). The effect of the lunar cycle on the distribution of abundance of the species collected in each interval of samples, during the 1st half of the night, was examined. The activity of female *L. intermedia* was depressed during the crescent moon and full moon phases (Kolmogorov–Smirnov test, $P < 0.01$ and $P < 0.05$ respectively; Fig. 2). New and waning phases of the moon did not effect on the behavior of females of this species.

DISCUSSION

Based on the premise that in the absence of moonlight, sand flies would exhibit positive phototaxis and be attracted to light traps, we would

Table 2. Mean abundance of most-abundant phlebotomine sand flies (both sexes) collected in different lunar phases with illuminated Shannon traps and Falcão light traps, in the microregion of Viçosa, Minas Gerais State, Brazil, between October 1999 and August 2000.[1]

	New			Crescent			Full			Three-quarter			
Species	Mean (SD)	Median	Total	Mean (SD)	Median	Total	Mean (SD)	Median	Total	Mean (SD)	Median	Total	Kruskal–Wallis test (*P*)
L. intermedia	23.12 (52.59)	5.50	185	4.08 (6.51)	0.50	49	14.31 (19.93)	5.00	229	31.50 (42.91)	3.50	2.52	4.898 (0.17)
Females	18.75 (45.42)	2.00	150	1.41 (2.31)	0.00	17	7.93 (11.90)	2.00	127	27.62 (37.61)	2.00	221	4.789 (0.18)
Males	4.37 (7.38)	1.50	35	2.66 (4.73)	0.00	32	6.37 (10.46)	2.00	102	3.87 (8.59)	1.00	31	2.129 (0.54)
L. whitmani	3.50 (3.89)	1.50	29	0.08 (0.28)	0.00	1	3.43 (7.32)	0.00	55	2.75 (6.25)	0.00	22	8.736 (0.03)[2]
Females	2.25 (3.10)	1.50	18	0.08 (0.28)	0.00	1	1.25 (2.56)	0.00	20	2.00 (4.56)	0.00	16	4.618 (0.20)
Males	1.37 (1.68)	1.00	11	0.00 (0.00)	0.00	0	2.18 (5.55)	0.00	35	0.75 (1.75)	0.00	6	8.421 (0.03)[2]
L. fischeri	0.75 (1.38)	0.00	6	0.25 (0.86)	0.00	3	0.68 (1.77)	0.00	11	1.87 (4.91)	0.00	15	2.116 (0.54)
Females	0.62 (1.40)	0.00	5	0.08 (0.28)	0.00	1	0.37 (0.80)	0.00	6	1.25 (3.15)	0.00	10	1.593 (0.66)
Males	0.12 (0.35)	0.00	1	0.16 (0.57)	0.00	2	0.31 (1.01)	0.00	5	0.62 (1.76)	0.00	5	0.162 (0.98)
L. lenti	1.25 (2.37)	0.50	10	0.25 (0.62)	0.00	3	0.37 (1.08)	0.00	6	0.25 (0.70)	0.00	2	4.426 (0.21)
Females	0.62 (1.06)	0.00	5	0.08 (0.28)	0.00	1	0.25 (0.77)	0.00	4	0.25 (0.70)	0.00	2	3.369 (0.33)
Males	0.62 (1.40)	0.00	5	0.16 (0.38)	0.00	2	0.12 (0.34)	0.00	2	0.00 (0.00)	0.00	0	2.361 (0.50)
Total	230			56			301			291			
n	8			12			16			8			

[1] *L.*, *Lutzomyia*; SD, standard deviation; *n*, number of samples.
[2] Statistically significant.

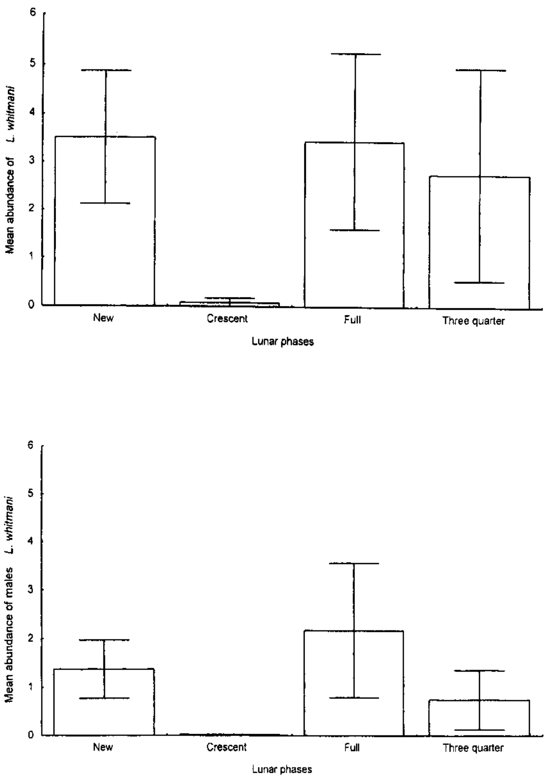

Fig. 1. Distribution of mean abundance of total and male *Lutzomyia whitmani* s.s. among lunar phases.

expect a maximum catch during a new moon. The light reflected by the moon in its brightest phases (crescent and full) should alter sand fly behavior, shifting their activity so that it does not coincide with the period when the moon would be most visible (between 2000 and 2300 h) and reducing the attractiveness of light traps through interference and diminished contrast.

Aguiar et al. (1985) noted that fewer sand flies were captured in Serra dos Órgãos, Rio de Janeiro State, Brazil, on brighter nights, because of the full moon. In this study, most captures occurred on darker nights, particularly those during the new and last quarter moon. Different results were obtained by Chadee (1992) when sampling *Anopheles bellator* Dyar and Knab in Trinidad. In this case, sampling under a full moon was highly productive, indicating that on brighter nights, host-seeking and even moving through the forest may be easier for the insects.

Guimarães et al. (2000) did not find a direct influence of the lunar cycle on populations of mosquitoes in the Parque Estadual da Serra do Mar, São Paulo State, Brazil. Although these authors suggested that habitats with bushy vegetation would permit greater penetration of moonlight, increasing the probability of interference in the behavior of *Aedes scapularis* (Rondani), data were insufficient to permit correlation of the lunar cycle with activity.

The results obtained in the present study with

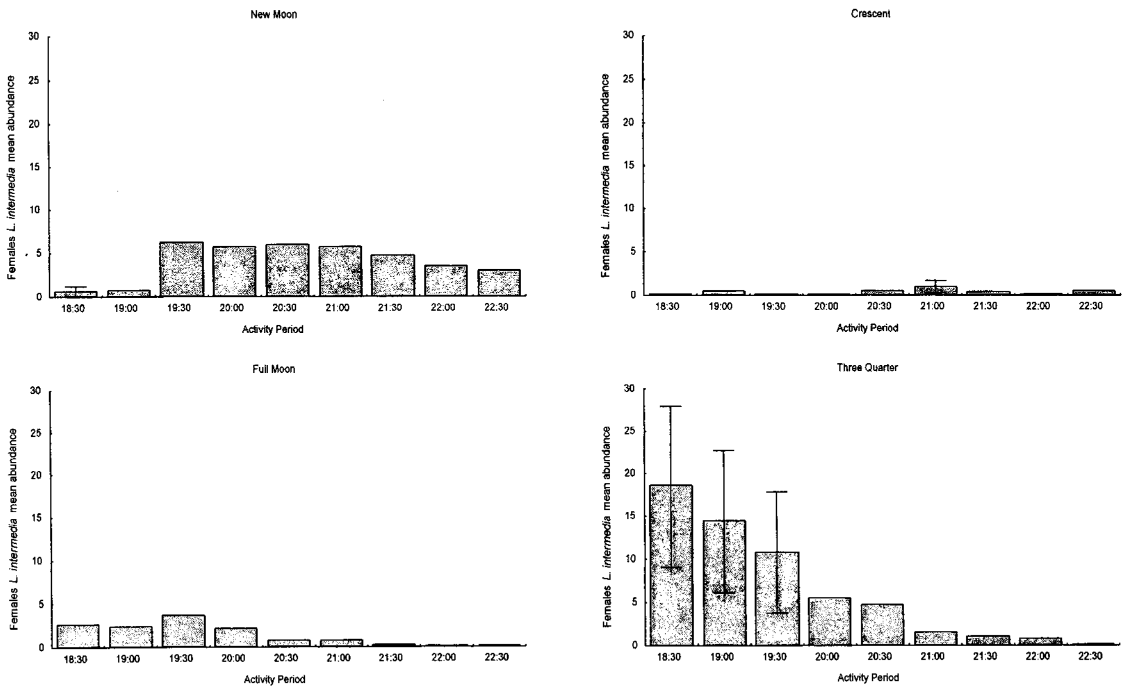

Fig. 2. Distribution of mean abundance of female *Lutzomyia intermedia* s.s. among sampling periods in relation to the lunar cycle.

respect to sand fly frequency and abundance during the different lunar phases indicated that the lunar cycle may be a secondary determinant of population fluctuations.

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